Management of the Ground Engaging Tools Through Using Classification and Forecast

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Abstract. The management of spare part has been a crucial thing regarding the availability and reliability of a machine. Managing of spare part inventory is different with managing of material at production process. The forecast of the spare part need with a special demand pattern needs a suitable method. Exponential Smoothing method that was often used giving forecast result that is not suitable with what the spare part really needs. In this present research, the Croston method is used for forecasting spare part demand. This method considers the mean of non-zero demand as well as the interval of it. Moreover, this method is going to be compared to Syntetos-Boylan Approximation (SBA) which is the advancement of the Croston method. Before classifying the spare part based on the analysis of FSN which is going to get the forecast spare part. From the error comparison, SBA method has less error score. It has least score on 14 kind of spare parts from the 16 spare parts, which already predicted. Meanwhile the 2 kind of spare parts has least score on Croston method.

Keywords: Croston Method, FSN Analysis, SBA Method, Spare Part

NOMENCLATURE

CR : Croston Method
GET : Ground Engaging Tools FSN
: Fast-Slow-Non Moving PTNNT: PT. Newmont Nusa Tenggara
PTTU : PT. Trakindo Utama
SBA : Syntetos-Boylan Approximation

A. INTRODUCTION

Availability and reliability of a machine are the important aspects for companies which use machines in running their business. Those both aspects protect machine in an ideal state [1]. Availability and reliability is related to maintenance. One of the factors that maintenance execution is done well is by the availability of spare part of machine. In order to conduct maintenance execution in a proper way, the availability of spare part should be kept in a certain amount, so that it is able to balance with the spare part demand needed. Bacchetti & Saccani (2012) stated that *there are several aspects which draw spare part demand and the management of spare part availability into a complex problem, they is the high amount of managed spare part and the encounter of either intermittent or lumpy demand* [2]. Intermittent demand is a demand which occur in an interval time which is not in order and concerned decrease as well as of them is various quantities. Meanwhile, lumpy demand is uneven in term of time and amount which needed variously, also, it requires a large amount of investment and longer responsive time than what has predicted. Another aspect is that the requirement of fast response to deal with downtime machine and the risk possibility of obsolete spare part.

Solving the management of the spare part availability is imperative, so that each spare part characteristic is known. Every single spare part possesses special characteristic that can be differed from material used in a production system. The main characteristic is on the spare part demand. The demand pattern of each spare part is different, i.e. slow moving, intermittent, erratic, or lumpy. It is crucial to comprehend the management of spare part availability in a company. Heretofore, the pattern of spare part demand is not similar to raw materials. The uniqueness of the spare part availability pattern is an irregular demand. The irregularity causes the spare part demand is difficult to be predicted, therefore it requires an accurate forecast method to bode the spare part demand.

There are a number of forecast methods which are developing nowadays, for instance the classic methods; exponential smoothing, moving average, and regression analysis, and recent and special methods; Croston [3], Syntetos-Boylan Approximation (SBA) [4], and Bootstraap [5]. Among those methods, Croston, SBA, and Boostrap method are the forecast methods which are used to bode the spare part demand. Ragnarsdottir et al. (2012) argued that *managing the spare part availability is quite different from managing raw material in production process* [6]. The irregular demand pattern causes forecast method used should be suitable with the demand pattern itself.

PT. Trakindo Utama (PTTU), Batu Hijau Division which engage in the unit of Heavy Equipment business as well as it is as the contractor of PT. Newmont Nusa Tenggara

(PTNNT) which involves in sorts of operational mining system which is integrated. The complex operational system and asset-incentive industry affect this company to extremely depend on the technical tools availability, such as unit of heavy equipment; Highway Truck, Auxillary Machine, Pump, Generator Set, etc. to ensure the progress of mining operation. It is thus spare part availability is one of the key in maintenance, whereby it functions to protect the equipment availability. Observing the operational system which is integrated in such a complex way at PTNNT, it is therefore, PTTU, Batu Hijau Division as the business partner should guarantee spare part availability and protect the mining operation progress. Each machine plays an important role in operation process; otherwise if a machine is in trouble, then the process will also be distracted.

Spare parts which are used in PTTU Batu Hijau Division are numerous. Hence, it needs to be categorized and classified. PTTU Batu Hijau Division categorizes and classifies spare parts into three categories as follow:

1. Fast : spare part has daily consumption level
2. Medium : spare part has weekly consumption level
3. Slow : spare part has monthly consumption level

However, neither is such categorization optimal nor theoretically uses basic classification. The initial result of the observation and the interview with the Inventory Department, in conducting the spare part forecast, PTTU Batu Hijau Division prioritizes historical data qualitatively. This needs to be researched further in order to determine best forecast technique of this case. Such technique, therefore, will be likely to decrease safety stock and management expense of spare part without, instead, decreasing its service level.

The purpose of the present study is to classify spare part based on the characteristics of it which use FSN analysis, determine spare part demand pattern, and analyze its relationship with spare part forecast as well as compare and analyze the accuracy level of both Croston method and SBA method.

B. METHOD

The phases conducted are:

Data Collection

The data that are needed in this study including:

a. Procurement of spare part policy in PTTU Batu Hijau Division
b. Data of spare part need of Heavy Equipment EX801/390DL, GR012/24H and RD008/854G units during the period of September 2013 – August 2015.
c. Data of spare part receipt of Heavy Equipment EX801/390DL, GR012/24H and RD008/854G units during the period of September 2013 – August 2015.
d. Data of Order Cost and Holding Cost of Heavy Equipment EX801/390DL, GR012/24H and RD008/854G units during the period of September 2013 – August 2015.

Spare Part Classification

Kharisma et al. n.d. argued that *spare part classification can help the spare part management in establishing the most appropriate layout through allocating the type of fast moving spare part which is near to reservation, so that it minimizes the effort of handling* [1]. Also, the management attention is focused on the non-moving spare part to be able to decide whether the spare part is needed in future or it should be kept. The experience shows that many industries which have been running for 15 years have non-moving spare part stock more than 50%.

In deciding category of F, S, and N, there are two things that should be done, which are average stay value and consumption rate.

Definition 1: Average stay is the mean duration of culmination of availability. The formula used is:

$$\textit{Average stay of the material} = \textit{Culmulative No of Inventory Holding} / (\textit{Total Quantity Receive} + \textit{Opening balance}) \quad (1)$$

Definition 2: Consumption rate is the availability usage level in a certain period of time which is depicted in the formula:

$$\textit{Consumption rate} = \textit{Total Issue Quantity} / \textit{Total Period Duration} \quad (2)$$

Demand Pattern and Characteristic Determination

From the characteristic spare part demand, there are two parameters, they are:

a. ADI – Average Inter-Demand Interval: the mean of interval between spare part demands. It is typically displayed in a period in which it is the time of referential interval that is used in a company to purchase spare part.
b. CV – Coefficient of Variation: measuring deviation standard of non-zero demand period as proportion of period of non-zero demand mean.

Forecast of Spare Part Demand

The demand forecast is done in order to know estimate demand needs accurately through using the exact forecast. Forecast uses Croston method (CR) and Syntetos-Boylan Approximation (SBA).

CR method separates the amount of updating demand (Z_t) and interval demand (P_t). Reviewing the period of t, it demand independent between time period, then the estimation of the amount of demands and inter-arrival times at the end t, Z_t, and P_t, will not change respectively. If transaction occurs, then $X_t>0$, therefore the estimation is updating by

Algorithm 1:

1: **If** $X_t = 0$ **then**
2: $Z_t = Z_{t-1}$
3: $Q_t = Q_{t+1}$
4: $P_t = P_{t+1}$
5: **Else**
6: $Z_t = \alpha X_t + (1- \alpha)Z_{t-1}$
7: $Q_t = 1$
8: $P_t = \alpha Q_t + (1- \alpha)P_{t+1}$
9: **End If**

Where:
X_t = Demand in period t
Z_t = Size (magnitude) of transaction in time t
P_t = Interval mean of non-zero demand in period t
α = Smoothing parameter for magnitude

Generally, demand forecast in each period at t

$$\text{[illegible]} = \frac{\text{[illegible]}}{\text{[illegible]}} \quad (3)$$

Syntetos-Boylan Approximation (SBA) method is the correction of CR method. Syntetos et al. (2005) argued that *genuine CR method is bias* [4]. Therefore, to fix the bias, Syntetos and Boylan proposed to decrease CR forecast method with a factor $1 - \frac{\alpha}{2}$, thus the SBA forecast method becomes

$$\text{[illegible]} = (1 - \text{[illegible]})\frac{\text{[illegible]}}{\text{[illegible]}} \quad (4)$$

The Methods of Forecast Evaluation

In this phase, the researcher conducts the forecasting process among forcast methods which are used to determine which method is the best and closer to reality.

C. Results and Discussion

Determination Spare Part Criticality

According to the interview with the expert inspector, spare part is decided critical based on the following considerations:

1. The Spare Part which has the highest number of damage.
2. The spare part which has been damaged, automatically the unit of heavy equipment is breakdown.

Among the 38 types of spare part being observed, there are 18 spare parts which considered critical. Below is the spare part which is used in the three units of heavy equipment along with its critical information.

Table 1. Spare Part Names and the Critical Information

EQUIP. NO.	MODEL	PART NAME	PART NO.	REMARK
EX801	390DL	Bucket	3311246 J800	
		Tip	4533646	Critical
		Pin Kit	3102788	Critical
		Adapter	3576516	
		Side Bar	3295957	
		Ret	1320999	
		Pin	3572689	
		Base Edge	3605996	
		Shroud Heel	1571027	
		Half Arrow	8J8176	
		Wear Strip	360-6018	
		Wear Strip	360-6014	
GR012	24H	Cutting Edge	1386440	Critical
		Bolt	1J3527	Critical
		Bolt	4J9058	Critical
		Nut	2J3507	Critical
		Washer	5P8250	Critical
		Shank	9J3139	
		Pin	8J2190	
		Cotter	2H3775	
		Tip Long	6Y0359	Critical
		Pin	1140358	Critical
		Ret	1140359	Critical
		Bit	1093118	
RD008	854G	Blade	1584534	
		Ctr	9W6658	Critical
		Ewl	9W6657	Critical
		Bolt	5P8823	Critical
		Wash	4K0684	Critical
		End Bit R/H	8E4541	
		End Bit L/H	8E4542	
		Side Bar	1250800	
		Pin	8E4708	
		Ret	4T4707	
		Sole Plate	1359668	Critical
		Bolt	2B1955	Critical

FSN Classification Analysis

The observed object consists of three heavy equipment units, which are EX801/390DL, GR012/24H and RD008/854G. The unit of EX801/390DL consists of two types of critical spare part, the unit of GR012/24H consists of nine critical spare parts, and the unit RD008/854G consists of seven critical spare parts. As in this case, the necessity of spare part classification of PTTU standard to compare with the results of the research will be needed. In determining the spare part classification by PTTU Standard, it can be seen from the consumption level in whole branches. The data are dynamic, it is thus each period will possess different standard. Below is the Standard of PTTU on August 2015 in classifying spare part for heavy equipment units EX801/390DL, GR012/24H, and RD008/854G.

Table 2. Spare Part Classification Standard of PTTU

EQUIP. NO./MODEL	PART NAME	PART NO.	STANDARD OF PTTU
EX801/390DL	Tip	4533646	F
	Pin Kit	3102788	F
GR012/24H	Cutting Edge	1386440	M
	Bolt	1J3527	F
	Bolt	4J9058	F
	Nut	2J3507	F
	Washer	5P8250	F
	Tip Long	6Y0359	F
	Pin	1140358	F
	Ret	1140359	F
RD008/854G	Ctr	9W6658	F
	Ewl	9W6657	F
	Bolt	5P8823	F
	Wash	4K0684	F
	Sole Plate	1359668	F
	Bolt	2B1955	M

After conducting calculation of average stay value and consumption rate to each spare part, it is obtained that there are several spare part which belong to F, S, and N category. It is depicted in the following FSN classification table.

Table 3. Spare Part Classification Category

EQUIP. NO./MODEL	PART NAME	PART NO.	FSN (AVERAGE STAY)	FSN (CONSUMPTION RATE)	STANDARD OF PTTU	FINAL CLASSIFICATION
EX801/390DL	Tip	453364	F	N	F	F
	Pin Kit	310278	N	S	F	S
GR012/24H	Cutting Edge	138644	N	N	S	N
	Bolt	1J352	N	N	F	S
	Bolt	4J905	N	S	F	S
	Nut	2J350	F	F	F	F
	Washer	5P825	F	F	F	F
	Tip Long	6Y035	S	N	F	S
	Pin	114035	S	S	F	F
	Ret	114035	N	S	F	S
RD008/854G	Ctr	9W665	N	N	F	S
	Ewl	9W665	N	N	F	S
	Bolt	5P882	N	S	F	S
	Wash	4K068	S	F	F	F
	Sole Plate	135966	F	N	F	F
	Bolt	2B195	F	N	S	S

Spare Part Demand Pattern

Spare part demand pattern consists of four categories; slow moving, intermittent, erratic, and lumpy. In order to determine which spare part pattern belong to certain category, it is necessary to conduct calculation of ADI and CV values. Here is the recap of the demand pattern for each spare part which is forecasted.

Table 4. Spare Part Demands Pattern

EQUIP. NO./MODEL	PART NAME	PART NO.	ADI	CV	DEMANDS PATTERN
EX801/390DL	Tip	4533646	2,00	1,19	Lumpy
	Pin Kit	3102788	1,26	0,87	Erratic
GR012/24H	Cutting Edge	1386440	1,33	0,90	Lumpy
	Bolt	1J3527	1,10	0,62	Erratic
	Bolt	4J9058	1,14	0,58	Erratic
	Nut	4J9058	1,00	0,53	Erratic
	Washer	5P8250	1,00	0,52	Erratic
	Tip Long	6Y0359	1,09	0,65	Erratic
	Pin	1140358	1,09	0,64	Erratic
	Ret	1140359	1,04	0,63	Erratic
RD008/854G	Ctr	9W6658	1,71	1,05	Lumpy
	Ewl	9W6657	1,50	0,99	Lumpy
	Bolt	5P8823	1,00	0,70	Erratic
	Wash	4K0684	1,00	0,56	Erratic
	Sole Plate	1359668	1,14	0,55	Erratic
	Bolt	2B1955	1,14	0,59	Erratic

Forecasting Method Analysis based on Error

In this research, the researcher uses two forecast methods; Croston and SBA. From these methods, the value of MAD and MAPE can be seen of each method which is its error value. The smaller the error value is, the better method is chosen. Croston method has the least error at the type of spare part which has interval mean within non-zero demand (ADI) which is quite distant and the variation coefficient value (CV) is higher compared to error forecast which possessed by SBA method. Of 24 periods of Croston method being observed, ADI is higher than 1,3 and CV is higher than 0,90. On the other hand, SBA method has the smallest error at the type of spare part which its ADI value is lower than 1,3 and CV 0,90. Below is the comparison of ADI, CV, and error forecast value to each type of spare part.

Table 5. Spare Part Error Forecast

	Tip 453646		Pin Kit 3102788		Cutting Edge 1386440		Bolt 1J3527		Bolt 4J9058		Nut 2J3507		Washer 5P8250		Tip Long 6Y0359	
	Croston	SBA	Croston	SBA	Croston	SBA	Croston	SBA	Croston	SBA	Croston	SBA	Croston	SBA	Croston	SBA
MAD	2,34	1,99	7,32	7,42	11,67	12,24	27,69	26,80	91,96	84,35	106,84	103,73	145,29	144,87	30,49	29,53
MAPE	79%	79%	58%	58%	48%	47%	69%	68%	82%	82%	88,4%	75,8%	84%	72%	209%	179%
ADI	2,00		1,26		1,33		1,10		1,14		1,00		1,00		1,09	
CV	1,19		0,87		0,90		0,62		0,58		0,53		0,52		0,65	

Table 6. Spare Part Error Forecast (*continued*)

	Pin 1140358		Ret 1140359		Ctr 9W6658		Ewl 9W6657		Bolt 5P8823		Wash 4K0684		Sole Plate 1359668		Bolt 2B1955	
	Croston	SBA	Croston	SBA	Croston	SBA	Croston	SBA	Croston	SBA	Croston	SBA	Croston	SBA	Croston	SBA
MAD	32,64	30,88	20,56	27,48	2,33	1,10	1,30	0,95	108,00	120,51	185,83	151,75	3,23	2,75	53,67	46,37
MAPE	59%	58%	57%	55%	45%	45%	53%	48%	168%	168%	86,9%	85,8%	58%	49%	80%	67%
ADI	1,09		1,04		1,71		1,50		1,00		1,00		1,14		1,14	
CV	0,64		0,63		1,05		0,99		0,70		0,56		0,55		0,59	

Analysis of Spare Part Availability Expense Comparison for each Forecasting Methods

According to the forecast results to the next three years, it is used to determine availability plan and expense needed. As the calculation obtained, it shows that spare part types which are forecasted using SBA and Croston method, which means the availability plan is constant. This occurs since the forecasting result is also constant.

The calculation of availability conducted is completed with the needed expense calculation. This expense calculation will be compared among other methods. This way, the method with the smallest error which either cost smallest expense or not will be found out. The following displays the comparison of total's expense needed in 2016, 2017, and 2018 respectively for each spare part.

Table 7. Comparison of Availability Expense Calculation for each Forecasting Method

EX801/390DL		Metode	2016	2017	2018	Total
Tip	4533646	SBA	$53.648,00	$85.120,00	$62.796,00	$201.564,00
		Croston	$64.232,00	$85.699,00	$68.295,00	$218.226,00
Pin Kit	3102788	SBA	$98.689,00	$83.134,00	$61.627,00	$243.450,00
		Croston	$81.676,00	$90.976,00	$53.758,00	$226.410,00
GR012/24H		Metode	2016	2017	2018	Total
Cutting Edge	1386440	SBA	$68.533,14	$70.284,79	$72.036,43	$210.854,36
		Croston	$79.480,93	$63.716,12	$76.415,55	$219.612,60
Bolt	1J3527	SBA	$80.551,00	$63.893,00	$78.772,00	$223.216,00
		Croston	$77.340,00	$56.753,00	$67.616,00	$201.709,00
Nut	2J3507	SBA	$56.746,00	$89.048,00	$54.754,00	$200.548,00
		Croston	$57.515,00	$87.767,00	$67.999,00	$213.281,00
Washer	5P8250	SBA	$51.431,00	$70.129,00	$85.455,00	$207.015,00
		Croston	$73.168,00	$66.140,00	$50.663,00	$189.971,00
Tip Long	6Y0359	SBA	$79.765,00	$66.765,00	$66.219,00	$212.749,00
		Croston	$82.559,00	$72.417,00	$68.765,00	$223.741,00
Pin	1140358	SBA	$63.091,00	$76.575,00	$73.315,00	$212.981,00
		Croston	$95.447,00	$54.803,00	$62.377,00	$212.627,00
Ret	1140359	SBA	$74.292,00	$62.919,00	$77.911,00	$215.122,00
		Croston	$85.606,00	$57.669,00	$97.565,00	$240.840,00
RD008/854G		Metode	2016	2017	2018	Total
Ctr	9W6658	SBA	$81.842,00	$93.186,00	$75.767,00	$250.795,00
		Croston	$58.853,00	$80.307,00	$51.446,00	$190.606,00
Ewl	9W6657	SBA	$97.429,00	$58.935,00	$73.181,00	$229.545,00
		Croston	$61.059,00	$99.251,00	$72.828,00	$233.138,00
Bolt	5P8823	SBA	$54.263,00	$81.684,00	$78.012,00	$213.959,00
		Croston	$53.326,00	$58.701,00	$78.671,00	$190.698,00
Wash	4K0684	SBA	$60.321,00	$61.176,00	$55.103,00	$176.600,00
		Croston	$65.948,00	$73.522,00	$50.322,00	$189.792,00
Sole Plate	1359668	SBA	$54.456,00	$90.339,00	$85.015,00	$229.810,00
		Croston	$76.406,00	$56.719,00	$89.826,00	$222.951,00
Bolt	2B1955	SBA	$70.755,00	$78.779,00	$87.547,00	$237.081,00
		Croston	$82.467,00	$87.766,00	$86.429,00	$256.662,00

The table above shows that the method which has the smallest error does not necessarily have smallest availability expense. The green one displays the forecasting method with the smallest error, while the yellow one is the smallest availability expense. Mostly, the forecasting methods which have smaller error, the availability expense is costly. It is only on Nut (Part No. 2J3507), Tip Long (Part No. 6Y0359), Ret (Part No. 1140359), Ewl (Part No. 9W6657), Wash (Part No. 4K0684) dan Bolt (Part No. 2B1955) with smaller error method which have small availability expense.

Conclusion

Spare Part which is used to forecast three units of heavy equipment belong to F and S category. The spare parts which belong to F are Tip (Part No. 4533646), Pin (Part No. 1140358), Washer (Part No. 5PB250), Nut (Part No. 2J3507), Sole Plate (Part No. 1359668) and Wash (Part No. 4K0684). Spare parts which belong to S are Pin Kit (Part No. 3102788), Bolt (Part No. 1J3527), Bolt (Part No. 4J9058), Tip Long (Part No. 6Y0359), Ret (Part No. 1140359), Ctr (Part No. 9W6658), Ewl (Part No. 9W6657), Bolt (Part No. 5P8823) and Bolt (Part No. 2B1955).

Spare part demand pattern in general are lumpy and erratic whereby ADI and CV value influence the error forecasting value. From the two forecasting methods which are conducted, SBA method has the smallest error value to all types of spare part, except Pin Kit (Part No. 3102788) and Cutting Edge (Part No. 1386440) which the smallest error is in the Croston Method. The forecasting method which has smaller error value does not necessarily have lower availability expense.

In future, FSN method needs to be compared to other methods in classifying spare part. Forecasting method are also needed to be attended, such as in using Monte Carlo simulation which will be compared to CR and SBA method.

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